DOCUMENT RESUME

ED 071 903 SE 015 540

TITLE	Project Physics Tests 5, Models of the Atom.
INSTITUTION	Harvard Univ., Cambridge, Mass. Harvard Project Physics.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C. Bureau of Research.
BUREAU NO	BR-5-1038
PUB DATE	68
CONTRACT	OEC-5-10-058
NOTE	32p.; Preliminary Version
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Achievement Tests; *Atomic Theory; Instructional Materials; Multiple Choice Tests; *Physics; Quantum Mechanics; Relativity; Secondary Grades; *Secondary School Science; *Testing
IDENTIFIERS	Harvard Project Physics

ABSTRACT

Test items relating to Project Physics Unit 5 are presented in this booklet. Included are 70 multiple-choice and 23 problem-and-essay questions. Concepts of atomic model are examined on aspects of relativistic corrections, electron emission, photoelectric effects, Compton effect, quantum theories, electrolysis experiments, atomic number and mass, particle scattering, charge-to-mass ratio, de Broglie wavelength, Balmer formula, Heisenberg's uncertainty principle, spectroscopic analysis, x-radiation, photons, Millikan oil-drop experiment, and atomic transition. Suggestions are made for time consumption in answering some items. Besides directions and a few illustrations for explanation purposes, related physical constants, definition, and equations are provided. The work of Harvard Project Physics has been financially supported by: the Carnegie Corporation of New York, the Ford Foundation, the National Science Foundation, the Alfred P. Sloan Foundation, the United States Office of Education, and Harvard University. (CC)

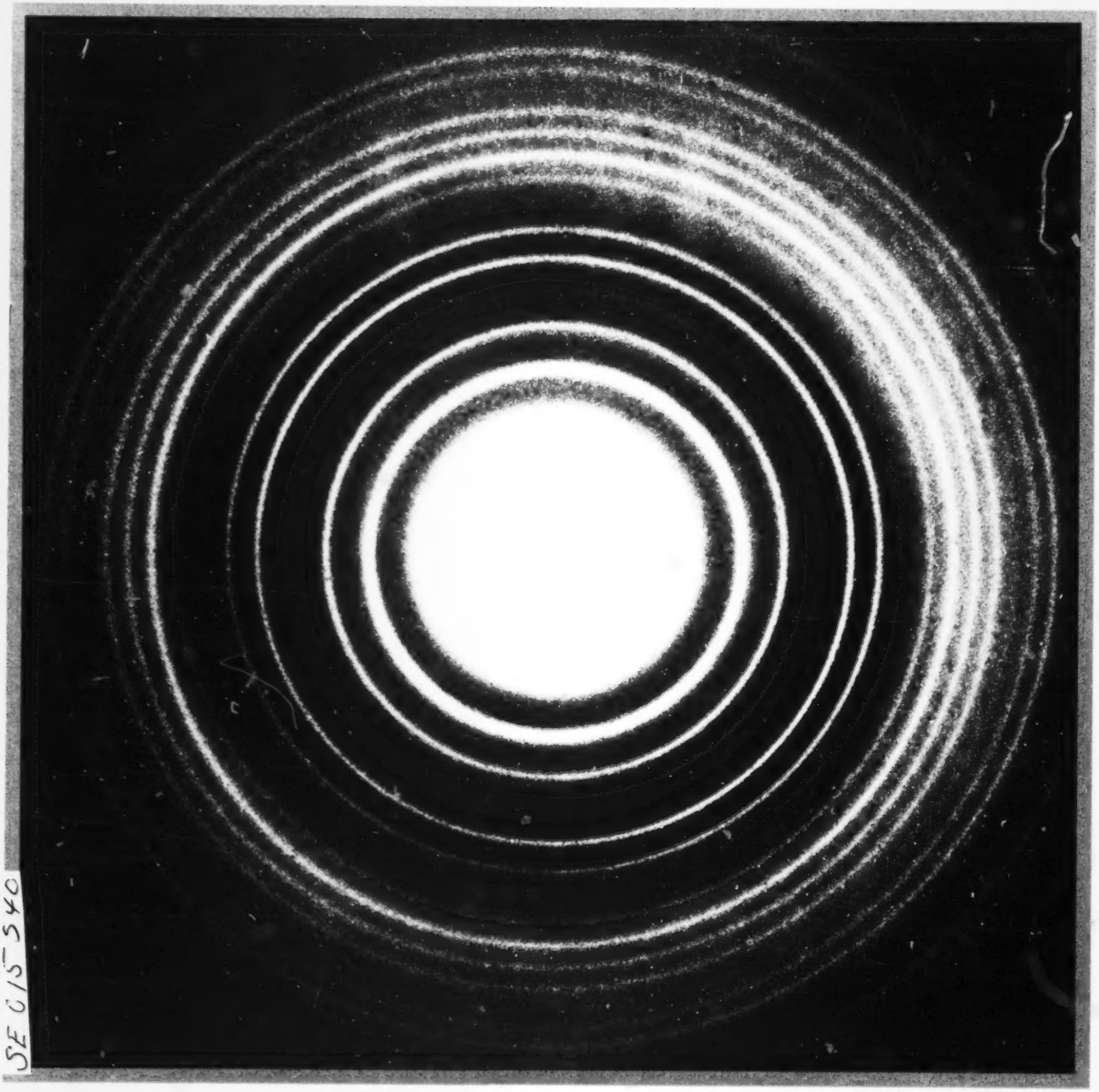
ED 071903

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
OFFICE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY

Project Physics **Tests** 5

An Introduction to Physics

Models of the Atom



SE 015 540

This document is a preliminary version of only one of many instructional materials being developed by Harvard Project Physics. Like all existing Project materials—text units, laboratory experiments, teacher guides, etc.—it is based on earlier drafts used in cooperating schools. Its development has profited from the help of many of the colleagues listed at the end of the units.

The work of Harvard Project Physics has been financially supported by the Carnegie Corporation of New York, the Ford Foundation, the National Science Foundation, the Alfred P. Sloan Foundation, the United States Office of Education, and Harvard University.

Cover Photo: Professor Harry Meiners, Rensselaer Polytechnic Institute.

Copyright © 1968, F. James Rutherford

Copyright is claimed until April 1, 1969. After April 1, 1969 all portions of this work not identified herein as the subject of previous copyright shall be in the public domain. Distribution of the public domain version at cost is planned by Project Physics Incorporated, a non-profit educational organization.

All persons making use of any part of these materials are requested to acknowledge the source and the financial support given to Project Physics by the agencies named above, and to include a statement that the publication of such material is not necessarily endorsed by Harvard Project Physics or any of the authors of this work.

ED 071903

TEST A

Directions

This test consists of fifteen multiple-choice questions and seven problem-and-essay questions divided into two groups. Answer ALL multiple-choice questions. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

NOTE: The numerical values of some physical constants, a definition, and equations that may be useful in this test are given below.

Physical Constants:

Velocity of light in vacuum (c) = 3.00×10^{8} m/sec

Planck's constant (h) = 6.61×10^{-34} J-sec

Definition:

1 Faraday = 96,500 coulomb/mole

Equations:

$$KE_{max} = hf - W$$

$$\lambda = \frac{h}{mv}$$

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$(\Delta x)\ (\Delta p) \geq \frac{h}{2\pi}$$

$$I\ (\text{ampere}) = \frac{q\ (\text{coulomb})}{t\ (\text{sec})}$$

TEST A

1. Which one of the following equations relates an increase in an object's mass with an increase in the object's speed?

A. $m = F/a$

B. $\frac{q}{m} = \frac{v}{BR}$

C. $\frac{1}{2} mv^2 = hf - W.$

D. $m = \frac{m_o}{\sqrt{1 - v^2/c^2}}$

E. $mv = \frac{hf}{c}$

2. Which of the following could not be explained in terms of classical physics?

1. the photoelectric effect
2. variation of mass with speed
3. the Compton effect

A. 1 only
B. 2 only
C. 3 only
D. 1 and 2 only
E. 1, 2 and 3

3. An electron from a hydrogen atom

A. is identical to an electron from an oxygen atom.
B. has greater rest mass than an electron from an oxygen atom.
C. is larger than an electron from an oxygen atom.
D. has greater charge than an electron from an oxygen atom.

4. A reasonable prediction, based on the evolution of previous scientific theories, is that in the future the quantum theory will

A. be replaced by a theory based on a mechanical model.
B. be replaced by a more general theory.
C. be shown to be wrong.
D. explain everything about nature.

5. A clean surface of potassium metal will emit electrons when exposed to blue light. If the intensity of the blue light is increased, which of the following will increase also?

1. the number of electrons ejected per second
2. the maximum kinetic energy of the ejected electrons
3. the charge of each ejected electron

A. 1 only
B. 2 only
C. 3 only
D. 1 and 2 only
E. 1, 2 and 3

6. In an electrolysis experiment, a certain amount of hydrogen is collected. If the experiment were repeated with 1/3 as much electric current, and 1/5 as much time, how much hydrogen would be collected?

A. 1/15 as much
B. 1/8 as much
C. 1/5 as much
D. 1/3 as much
E. 1/2 as much

7. ALL EXCEPT ONE of the following terms can be applied to both an x ray and an atom of hydrogen. Find the exception.

A. wavelength
B. momentum
C. velocity
D. rest mass
E. energy

8. Bohr's atomic model

A. allows only certain values of angular momenta for the orbital electron of hydrogen.
B. explains the spectra of elements whose atoms have more than one electron in the outermost shell.
C. assumes that electrons have wave properties.

9. In the modern periodic table, the elements are arranged in order of increasing

A. atomic mass.
B. atomic number.

10. Which of the following entered significantly into the determination of q/m for electrons in J. J. Thomson's experiment?

1. A force acts upon a moving electron in a gravitational field.
2. A force acts upon a moving electron in an electric field.
3. A force acts upon a moving electron in a magnetic field.

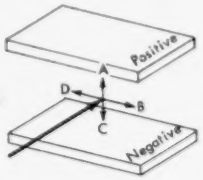
A. 1 and 2 only
B. 1 and 3 only
C. 2 and 3 only
D. 1, 2 and 3

11. In a scattering experiment, some alpha particles directed towards a gold foil come straight back. At the point of closest approach of an alpha particle to the nucleus of the gold atom, the alpha particle must have had zero

A. kinetic energy.
B. potential energy.
C. electrical energy.
D. acceleration.
E. charge.

12. A beam of electrons is directed between two charged plates as indicated in the diagram at the right. Once the beam is between the plates it will

A. curve in direction A.
B. curve in direction B.
C. curve in direction C.
D. curve in direction D.
E. continue in a straight line.



13. When the speed of an electron increases, the measured value of the charge-to-mass ratio is

A. increased because the mass decreases.
B. increased because the charge increases.
C. decreased because the mass increases.
D. decreased because the charge decreases.
E. unchanged.

14. No physicist has been able to think of an experiment that could reveal the exact position of an electron in a given atom. Therefore, modern physicists

A. assume that the electrons take positions predicted by Bohr's theory.
B. have developed a theory that states that the position of an electron in an atom cannot be found precisely.
C. look forward to the time when such experiments will be done.

15. Which statement about an electron is false? Moving electrons

A. have masses that are independent of speed.
B. may be diffracted.
C. can be deflected by a magnetic field.
D. can be deflected by an electric field.

PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following five questions.

1. It was found by experiment that the ratio of charge to mass of a certain particle was 1/1836 times the ratio of charge to mass of an electron. State at least two different hypotheses that might account for this observation.

2. The compound zinc oxide (ZnO) contains equal numbers of atoms of zinc and oxygen. The atomic mass of zinc is 65.37 and the atomic mass of oxygen is 15.99. Calculate the percentage by mass of zinc in zinc oxide.

3. What factors influence the amount of deflection of a beam of electrons by a magnetic field?

4. Explain the meaning of the equation $mvr = \frac{nh}{2\pi}$ in Bohr's model of the atom.

5. Calculate the de Broglie wavelength of a neutron (mass = 1.67×10^{-27} kg) traveling at 10^8 meter/second.

PROBLEM-AND-ESSAY QUESTIONS

Group Two

Answer ONE of the following two questions.

6. The generalized Balmer formula that describes the hydrogen spectrum is

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) .$$

In the Bohr model the energ of the radiation emitted or absorbed when a hydrogen atom goes from an initial energy state to a final energy state is

$$hf = \frac{E_1}{n_f^2} - \frac{E_1}{n_i^2} .$$

If $E_1 = R_H \cdot hc$, show that the Balmer formula may be derived from the Bohr formula.

7. a) Write a brief statement of Heisenberg's uncertainty principle.
   b) If the uncertainty in the position of an electron is 10^{-10} meters, what is the uncertainty in its momentum?

TEST B

Directions

This test consists of fifteen multiple-choice questions and eight problem-and-essay questions divided into two groups. Answer ALL multiple-choice questions. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

NOTE: The numerical values of some physical constants, a definition, and equations that may be useful in this test are given below.

Physical Constants:

Velocity of light in vacuum (c) = 3.00×10^{8} m/sec

Planck's constant (h) = 6.61×10^{-34} J-sec

Definition:

1 Faraday = 96, 500 coulomb/mole

Equations:

$$KE_{max} = hf - W$$

$$\lambda = \frac{h}{mv}$$

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$(\Delta x)\ (\Delta p) \geq \frac{h}{2\pi}$$

$$I\ (\text{ampere}) = \frac{q\ (\text{coulomb})}{t\ (\text{sec})}$$

TEST B

1. An electron has a rest mass of 9.1×10^{-31} kilograms. Each electron in a certain beam has a mass of 9.6×10^{-31} kilograms. Therefore, we can conclude there has been an increase in the electron's

1. kinetic energy.
2. speed.
3. rest mass.

A. 1 only
B. 2 only
C. 3 only
D. 1 and 2 only
E. 1, 2 and 3

2. An oxygen molecule is made up of atoms, nuclei and electrons. If one lists these for oxygen in order of decreasing mass, with the most massive listed first, which one of the following lists is correct?

A. electron, nucleus, atom
B. nucleus, atom, electron
C. nucleus, electron, atom
D. atom, nucleus, electron
E. atom, electron, nucleus

3. Most gases can be analyzed by means of a spectroscope because each element

A. can be recognized when magnified up to 100,000 times its normal size.
B. occupies a unique position in the periodic table.
C. when heated to a high temperature emits light with a characteristic set of wavelengths.
D. has a different atomic mass.

4. An electron from a hydrogen atom

A. is identical to an electron from an oxygen atom.
B. is more massive than an electron from an oxygen atom.
C. is larger than an electron from an oxygen atom.
D. has greater charge than an electron from an oxygen atom.

5. Which of the following statements is (are) correct?

1. X rays travel at the speed of light.
2. X rays may be produced when high-energy electrons are stopped by a target.
3. X rays are high-energy electrons.

A. 1 only
B. 1 and 2 only
C. 1 and 3 only
D. 2 and 3 only
E. 1, 2 and 3

6. An understanding of the photoelectric effect was most important to the development of

A. the quantum theory of light.
B. Thomson's atomic model.
C. Faraday's second law of electrolysis.
D. the periodic table of elements.

7. Evidence that atoms might have structure was found in

1. electrolysis experiments.
2. the periodic properties of elements.
3. cathode-ray experiments.

A. 1 only
B. 2 only
C. 3 only
D. 1 and 3 only
E. 1, 2 and 3

8. Rutherford's model of the atom accounted for the

A. stability of the nucleus.
B. stability of the electron orbits.
C. line spectra of elements.
D. scattering of alpha particles by metal foils.
E. scattering of x rays by metal foils.

9. Which one of the following electromagnetic radiations has photons of the greatest energy?

A. radio
B. infrared
C. visible light
D. ultraviolet
E. x rays

10. In a letter to Max Born in 1926 Einstein wrote:

> The quantum mechanics is very imposing. But an inner voice tells me that it is still not the final truth. The theory yields much, but it hardly brings us nearer to the secret of the Old One. In any case, I am convinced that He does not throw dice.

In this statement, what characteristic of quantum mechanics was Einstein objecting to?

A. The predictions of quantum mechanics can only be expressed as probabilities.
B. Quantum mechanics considers both wave and particle properties of matter.
C. The development of quantum mechanics involved very complicated mathematics.

11. Physicists refer to the dual nature of matter: matter has particle properties and wave properties. However, the wave property of large, massive objects is NOT observed because

A. this dual nature applies only to matter on the atomic scale.
B. their accelerations are too small.
C. their wavelengths are too small to detect.
D. their speeds are too small.
E. they do not emit photons.

12. The following men made important contributions to our understanding of atomic structure.

1. Bohr
2. Dalton
3. Schrödinger

If one lists the names in order of their contribution, with the earliest listed first, they would be arranged

A. 1, 2, 3.
B. 2, 1, 3.
C. 2, 3, 1.
D. 3, 1, 2.
E. 3, 2, 1.

13. The model of the atom used in quantum mechanics is

A. the planetary model described by Bohr.
B. similar to Bohr's model, but with elliptical orbits for the electrons.
C. a mathematical wave equation.
D. the "raisin pudding" model of electrons imbedded in positive electricity.

14. The Millikan oil-drop experiment was the first conclusive experimental demonstration that

A. electric charge is found as multiples of a certain unit of charge.
B. all electrons have a negative charge.
C. electrons are particles.
D. electrons have wave properties.
E. all atoms contain electrons.

15. The combining capacity of an element is called its

A. atomic number.
B. valence.
C. atomic mass.

PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following five questions.

1. What is meant by the expression "wave-particle dualism?"

2. Describe two shortcomings of Bohr's model of the atom.

3. How is the energy of a photon related to properties of the electromagnetic wave with which it is associated?

4. State one important consequence of the periodic table of elements formulated by Mendeleev.

5. Although the alchemists failed in their efforts to transmute ordinary metals into gold, their work has had a profound influence on the development of certain areas of science as we know them today. Describe briefly the role played by alchemy in the process by which modern chemistry evolved.

PROBLEM-AND-ESSAY QUESTIONS

Group Two

Answer ONE of the following three questions.

6. Select ONE of the following experiments.

   J. J. Thomson's q/m experiment
   Millikan's oil-drop experiment
   Photoelectric effect experiments
   Faraday's electrolysis experiment
   Rutherford's alpha-particle scattering experiment

   a) Sketch a diagram of the apparatus used in the experiment.
   b) Explain the significance of the experiment in the development of present ideas about the atom.

7. a) What role does the postulate "matter consists of indivisible atoms" play in the development of Dalton's atomic theory?
   b) The atomic mass of element A is 6 times that of element B. In a compound containing only A and B, it is found that there is 3 times as much A as there is B (by weight). That is, an 8-gram sample of the compound contains 6 grams of A and 2 grams of B. What is a possible formula for this compound?

8. Franck and Hertz found that electrons lose only certain amounts of kinetic energy in collisions with atoms of a gas. The experiment involved measuring the kinetic energy of electrons before and after they passed through a sample of gas.

   Sketch a diagram of an apparatus that could be used to make these measurements.

TEST C

Directions

Each of the forty items in this test has five possible responses. You are to select the one response which best answers the question and blacken the appropriate space on the answer sheet provided with the test.

NOTE: The numerical values of some physical constants, a definition, and equations that may be useful in this test are given below.

Physical Constants:

Velocity of light in vacuum (c) = 3.00×10^{8} m/sec

Planck's constant (h) = 6.61×10^{-34} J-sec

Definition:

1 Faraday = 96,500 coulomb/mole

Equations:

$$KE_{max} = hf - W$$

$$\lambda = \frac{h}{mv}$$

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$(\Delta x)\ (\Delta p) \geq \frac{h}{2\pi}$$

$$I\ (\text{ampere}) = \frac{q}{t}\ \frac{(\text{coulomb})}{(\text{sec})}$$

TEST C

1. In a scattering experiment, some alpha particles directed toward a gold foil come straight back. At the point of closest approach of an alpha particle to the nucleus of the gold atom, the alpha particle must have had zero

A. kinetic energy.
B. potential energy.
C. electrical energy.
D. accelation.
E. charge.

2. ALL EXCEPT ONE of the following are predictions of the special theory of relativity. Which one is the exception?

A. Photons have momentum.
B. The mass of a body increases with its speed.
C. Electrons in an atom have certain discrete energies.
D. Kinetic energy can be converted into matter.

For questions 3 to 6, use the following to select the phenomenon that correctly completes the sentence.

A. scattering of alpha particles by gold foil.
B. bright line spectra of hydrogen atoms.
C. emission of electrons from metal surfaces struck by electromagnetic radiation of different frequencies.
D. diffraction of electrons by crystals.
E. scattering of x rays by electrons.

3. The concept of a nuclear atom was established from experiments on the

4. The momentum of a photon was demonstrated in experiments on the

5. The wave character of matter was confirmed by

6. Bohr's theory was successful in explaining

7. In an electrolysis experiment 10.0 cubic centimeters of hydrogen gas is collected. If the experiment were repeated using the same amount of water, 1/3 as much electric current, and 1/5 as much time, how much hydrogen would be collected?

A. 0.67 cm^3
B. 1.00 cm^3
C. 1.67 cm^3
D. 2.00 cm^3
E. 3.33 cm^3

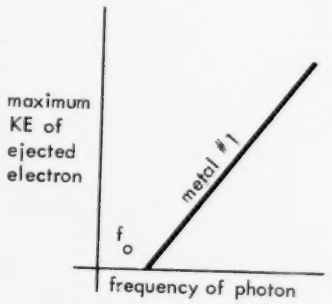
8. The success of the Bohr theory rested primarily on the fact that it

A. had a firm theoretical basis in quantum physics.
B. accounted for the electrical properties of matter for the first time.
C. was a consequence of Einstein's relativity theory.
D. explained the observed spectrum of hydrogen.
E. explained the properties of the nucleus.

Questions 9 and 10 refer to the graph at the right that displays the results of a photoelectric effect experiment.

9. The symbol f_o represents

A. Planck's constant.
B. The work function for metal #1.
C. the threshold frequency for metal #1.
D. the energy of an ejected electron.



10. The slope of the line labeled metal #1 equals

A. Planck's constant.
B. the work function for metal #1.
C. the threshold frequency for metal #1.
D. the energy of an ejected electron.

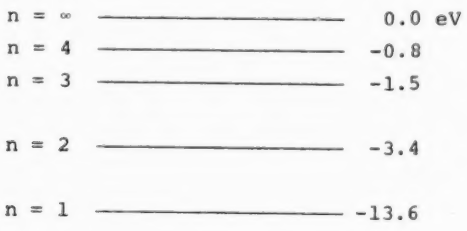
11. The unexpected finding about the scattering of alpha particles by gold foil was that

A. most particles went through the foil.
B. some particles were deflected through large angles.
C. scintillations were observed in the detector.
D. scattering varied with foil thickness.
E. alpha particles were more massive than cathode rays.

12. The "electron-volt" is a unit of

A. electric charge.
B. electric current.
C. energy.
D. potential difference.
E. rate of flow of electricity.

Questions 13 and 14 refer to the following diagram that gives the energies of some stationary states of hydrogen.



13. How much energy is emitted when an atom makes a transition between the stationary states designated by n = 3 and n = 2?

A. 1.5 eV
B. 1.9 eV
C. 3.4 eV
D. 4.9 eV
E. 10.2 eV

14. If hydrogen atoms, as described by the Bohr model, are excited to the stationary state designated by n = 3, how many different frequencies of radiation may be emitted by the atoms?

A. 1
B. 2
C. 3
D. 4
E. 5

15. Which of the following three statements is (are) true of cathode rays?

1. They are emitted by a variety of cathode materials.
2. Their path may be bent by magnetic fields.
3. Their path may be bent by electric fields.

A. 1 only
B. 1 and 2 only
C. 1 and 3 only
D. 2 and 3 only
E. 1, 2 and 3

16. According to classical electromagnetic theory, which of the following should occur in an atomic model that has electrons revolving in orbits around the nucleus?

1. Electrons should lose energy and fall into the nucleus.
2. Electrons should emit radiation continually.
3. Electrons should fly away from the nucleus.

A. 1 only
B. 2 only
C. 3 only
D. 1 and 2 only
E. 2 and 3 only

17. A beam of alpha particles with kinetic energy 3MeV is directed at a gold foil 1000 atoms thick. A second beam of alpha particles with kinetic energy 3 MeV is directed at a silver foil 1000 atoms thick.

A. The number of α particles scattered back by both foils will be identical.
B. The number of α particles scattered back by the gold foil will be different from the number scattered back by the silver foil.
C. Each foil will scatter all the particles directed at it.
D. There will be no scattering by either foil.

18. A clean surface of potassium metal will emit electrons when exposed to blue light. If the intensity of the blue light is increased, which of the following will also increase?

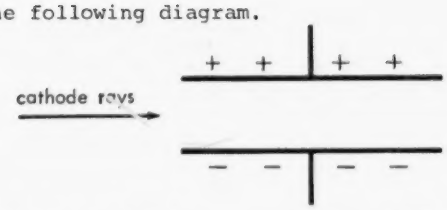
1. The number of electrons ejected per second.
2. The maximum kinetic energy of the ejected electrons.
3. The charge of each ejected electron.

A. 1 only
B. 2 only
C. 3 only
D. 1 and 2 only
E. 1, 2 and 3

19. X rays are

A. low-energy cathode rays.
B. high-energy photons.
C. ionized gas molecules.
D. waves accompanying photoelectrons.
E. particles traveling at speeds just below the speed of light.

Question 20 refers to the following diagram.



20. A beam of cathode rays traveling between two parallel plates, one positively charged and the other negatively charged,

A. is deflected towards the positive plate.
B. is deflected towards the negative plate.
C. is not deflected.

21. CuO and Cu_2O are two compounds of copper and oxygen. If 4 grams of copper combine with 1 gram of oxygen to form CuO, what weight of copper will combine with 1 gram of oxygen to form Cu_2O?

A. 1/4 g
B. 1/2 g
C. 2 g
D. 4 g
E. 8 g

22. Mercury vapor, when conducting a current, appears bluish-green. What is observed when the light from glowing mercury vapor is analyzed in a spectroscope?

A. a series of discrete lines
B. a series of irregular bluish-green flashes
C. a bluish-green glow
D. the entire visible light spectrum with some dark lines

23. Millikan's charged oil-drop experiment was the first conclusive experimental demonstration that

A. electric charge is found as multiples of a certain unit charge.
B. all electrons have a negative charge.
C. electrons are particles.
D. electrons have wave properties.
E. all atoms contain electrons.

Questions 24 to 26 refer to the following table that gives some data from electrolysis experiments.

Element	Atomic Mass	Valence	Quantity of element produced by one faraday of charge
Hydrogen (H)	1.0	1	1.0 gram
Zinc (Zn)	65.0	2	
Phosphorus (P)		3	10.3 gram

24. The quantity of zinc deposited by one faraday of electric charge is

A. 21.7 grams.
B. 32.5 grams.
C. 65 grams.
D. 130 grams.

25. The atomic mass of phosphorus is

A. 3.4.
B. 10.3.
C. 20.6.
D. 30.9

26. The most obvious formula for a compound of hydrogen and phosphorus is

A. HP
B. HP_2
C. HP_3
D. H_3P
E. H_2P_3

27. Physicists are willing to accept the wave-particle dualism because

A. the waves associated with particles are too small to be measured.
B. two theories are always better than one.
C. both wave and particle descriptions are needed to understand experimental results.
D. the dualism is confirmed by the theory of relativity.

28. Einstein explained the photoelectric effect by assuming that

A. the charge of an electron increases with speed.
B. atoms do not radiate energy from stationary states.
C. the mass of an electron increases with speed.
D. light consists of quanta of energy.
E. the energy of light increases with speed.

29. ALL EXCEPT ONE of the following are properties of x rays. Which one is the exception?

A. They penetrate light materials.
B. They ionize gases.
C. They are deflected by magnetic fields.
D. They discharge electrified bodies.
E. They are diffracted by crystals.

30. Evidence for the momentum of photons has been observed in experiments on the

A. diffraction of electrons by crystals.
B. mass increase of rapidly moving electrons.
C. scattering of x rays by electrons.
D. scattering of alpha particles by gold foil.
E. collisions of electrons with hydrogen atoms.

31. ALL EXCEPT ONE of the following are true of an electron of rest mass m_o moving with high speed. Which one is the exception?

A. Its mass is greater than m_o.
B. Its momentum is greater than $m_o v$.
C. It behaves also like a wave train of wavelength h/p.
D. Its kinetic energy is greater than $1/2\ m_o v^2$.
E. Its charge is greater than q_e.

32. The model of the atom used in quantum mechanics is

A. the planetary model described by Bohr.
B. similar to Bohr's model, but with elliptical orbits for the electrons.
C. mathematical.
D. the "raisin pudding" model of electrons dispersed in positive electricity.
E. a small solid sphere.

33. Bohr dealt with the dilemmas of the planetary model of atoms by

A. adjusting the data to fit his theory.
B. postulating that parts of classical theory did not apply.
C. postulating that atoms are unstable.
D. postulating that electrons have no energy.
E. disproving the Balmer formula.

34. The wave-particle dualism of matter can be confirmed experimentally for

A. electrons.
B. baseballs.
C. planets.
D. stars.
E. water waves.

35. The conclusion that the atom has a tiny, charged nucleus was first reached from

A. the evidence that x rays can ionize molecules.
B. the evidence that x rays can pass through matter.
C. the calculation of the distance between the nucleus and the electron in hydrogen atoms.
D. the calculation that ll series of the hydrogen spectrum are described by the equation $1/\lambda = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$.
E. the evidence that some α particles are deflected through large angles by thin slices of matter.

36. ALL EXCEPT ONE of the following are conclusions that can be drawn from a quantitative study of electrolysis of water. Which one is the exception?

A. Water is not an element.
B. Matter has electricity associated with it.
C. Hydrogen and oxygen are elements.
D. In water, hydrogen and oxygen carry opposite charges.
E. The mass of oxygen obtained is proportional to the amount of electric charge that passes through the electrolysis apparatus.

Questions 37 to 39 are statements that relate most directly to one of the following theories. Select the appropriate theory.

A. Bohr's theory
B. Heisenberg's uncertainty principle
C. Newton's universal theory of gravitation
D. Einstein's relativity theory

37. The mass of a moving object increases as its speed increases.

38. There is a limit to the accuracy of the simultaneous measurement of the velocity and position of a moving electron.

39. The angular momentum of an electron in a hydrogen atom can have only the values $h/2\pi$, $2h/2\pi$, $3h/2\pi$ ....

40. The Franck-Hertz experiment on the energy of electrons after passing through a gas provided evidence for the concept of

A. discrete atomic energy levels.
B. momentum of photons.
C. a plum pudding atom.
D. Compton scattering.
E. electron wavelengths.

TEST D

Directions

This test consists of 8 questions in two groups. Answer only FOUR of the five questions in Group One, and only TWO of the three questions in Group Two. Spend about 5 minutes on each of the questions from Group One, and 10 minutes on each of the questions from Group Two.

NOTE: The numerical values of some physical constants, a definition, and equations that may be useful in this test are given below.

Physical Constants:

Velocity of light in vacuum (c) = 3.00×10^{8} m/sec

Planck's constant (h) = 6.61×10^{-34} J-sec

Definition:

1 Faraday = 96,500 coulomb/mole

Equations:

$$KE_{max} = hf - W$$

$$\lambda = \frac{h}{mv}$$

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$(\Delta x)\ (\Delta p) \geq \frac{h}{2\pi}$$

$$I\ (\text{ampere}) = \frac{q\ (\text{coulomb})}{t\ (\text{sec})}$$

TEST D

Group One

Answer only FOUR of the five questions in this group.

1. Faraday's law of electrolysis relates a particular amount of electric charge (the faraday) with the atomic mass and valence of an element. What is this relation? Explain how this relation implies that electricity may be atomic (quantized) in nature.

2. What is one implication of the Millikan oil-drop experiment?

3. What aspects of the atom not included in Rutherford's idea of a nuclear atom were later explained by Bohr's model?

4. If the work function of a metallic surface is 2×10^{-18} joules, what is the lowest frequency of light that will release electrons from this surface?

5. What happens to the relativistic mass of an electron as its speed approaches the speed of light?

Group Two

Answer only TWO of the three questions in this group.

6. When 96,500 coulombs of charge (1 faraday) pass through water, 1.00 gram of hydrogen and 8.00 grams of oxygen are released. How much hydrogen and how much oxygen will be produced when a current of 3.00 amperes is passed through water for 60 minutes (3600 seconds)?

7. Each of the following equations symbolically represents a key advance in physics. Select two of these equations and describe its role in the development of modern physics.

I. $KE_{max} = hf - W$

II. $\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$

III. $m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}}$

IV. $\lambda = \frac{h}{mv}$

V. $(\Delta x)\ (\Delta p) \geq \frac{h}{2\pi}$

8. Compare the atomic theory of the Greeks with the atomic theories developed by scientists late in the nineteenth century.

This test is the property of HARVARD PROJECT PHYSICS. Upon request it is to be returned to Pierce Hall, 29 Oxford Street, Cambridge, Massachusetts, 02138.